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# Vibration Measurement and Verification of Ride Comfort When a Manual Attendant-Controlled Wheelchairs Is Running

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## ABSTRACT

The ire pressure of manual attendant-controlled wheelchairs was measured in four pressure conditions: 80, 160, 240, and 320 kPa. Ten trials were made each tire pressure (total of 40 times). The maximum power spectrum, frequency at the maximum power spectrum, and integral value were obtained from the fast Fourier transform analysis data for acceleration in three directions measured using the triaxial accelerometer, and the trends caused by changes in tire pressure were evaluated. Tire pressure indicators were attached to both the rear wheels of the manual attendant-controlled wheelchairs, and a dummy weight of 50 kgf was placed on the seat. Acceleration in three directions, including up–down, front–back, and left–right directions, was measured using a three-axis accelerometer attached to a heavy object. Riding comfort was evaluated using the SD method, and stationary and running evaluations were performed. For both static and running conditions, the evaluation consisted of three items, including sitting comfort, sense of security, and sitting comfort of the buttocks, and strength of shaking while running. Responses were obtained on a 5-point scale (1–5). In this study, an air pressure indicator for English valves was attached to manual attendant-controlled wheelchairs, and vibration measurements were performed under controlled conditions. The experiments using the manufactured vibration-measuring device revealed that vibration tends to increase as the tire pressure rises. Furthermore, the higher the tire pressure, the worse the ride comforts

**Keywords:** Wheelchairs, Tire pressure, Vibration, Ride comfort, Sensory test

## INTRODUCTION

The number of people with physically disabilities in Japan was approximately 4.28 million in 2016, and the number is increasing annually. In addition, 1.93 million people are considered to have physical disabilities. Furthermore, the aging of the population is expected to progress in Japan. Therefore, the demand for assistive devices is expected to increase annually. Among assistive devices, wheelchairs are used by both older people and those who are physically handicapped. Specifically, self-propelled wheelchairs are also used as assistive wheelchairs by caregivers in conjunction with assistive wheelchairs. However, wheelchair users experience motion sickness, discomfort, and annoyance because of vibrations during movement (Di Giovine et al., 2015a; 2015b; Cook and Polgar, 2008; Kitazaki and Griffin, 1998; LaPlante and Stephen Kaye, 2010; Wilder et al., 1994; Booka et al., 2015).

One of the factors that affect the ride comfort of a wheelchair user is tire pressure. However, to what extent the tire pressure of the wheelchair affects comfort is not yet known. One of the reasons is that the tire pressure of the English valve used in wheelchairs cannot be measured accurately. Therefore, to address this issue, we developed a tire pressure indicator with the cooperation of Hiroshima International University. This study aimed to evaluate the influence of tire pressure change on the vibration of an assistive wheelchair using the developed tire pressure indicator. In addition, for self-propelled wheelchairs to run at a constant speed, we used an electric wheelchair and manufactured a device to push the self-propelled wheelchair and obtain reliable data.

## VIBRATION MEASUREMENT EXPERIMENT

### Expermental Method

A dummy heavy object was placed on the seat of the assisted wheelchair with the vibration measurement device, and a triaxial accelerometer was attached to it. In addition, an electric wheelchair was run at a constant speed on uneven road surfaces at regular intervals. Fig. 1 shows the outline of the vibration-measuring device manufactured in this study.

### Experment Outline

### Vibration Measurement

The tire pressure indicators made for this study were attached to both sides of the rear wheels of the assistive wheelchair, and a 50-kgf dummy weight was placed on the seat. Acceleration in three directions, up-down, front–back and left–right, was measured by a three-axis accelerometer attached on the heavy object.

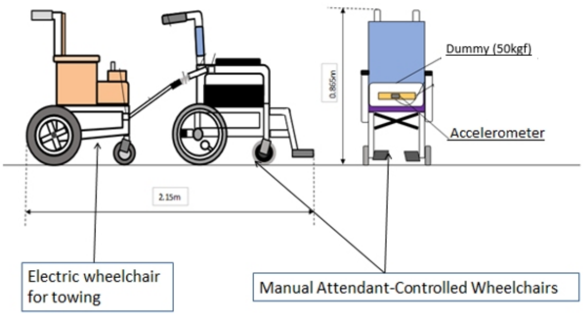


**Figure 1:** Experimental device. (a) Side view. (b) Front view.

## Experimental Methods

The vibration-measuring device shown in Fig. 1 is run on a linear block. A linear block of 300-mm square was used. When spread, it is 6.0 m long and 0.9 m wide. The manual assistive wheelchair was pushed out by the electric wheelchair so that the traveling speed was 0.33 m/s. Fig. 2 shows the outline of the experiment. The tire pressure of the manual assistive wheelchair was measured in four pressure conditions: 80, 160, 240, and 320 kPa. Ten trials were made for each tire pressure, totaling to 40 times. Table 1 shows the measurement pattern. The FFT analysis was performed using numerical analysis software for acceleration in three directions measured by a triaxial accelerometer. MATLAB (MathWorks Inc., Natick, USA) was used for the numerical analysis. The maximum power spectrum, frequency at the maximum power spectrum, and integral value from the FFT-analyzed data were obtained. Then, how they change with changes in tire pressure was evaluated.

## Experimental Results

FFT analysis was performed on the measured acceleration data in each axial direction. The results of the comparison of each tire air pressure and the integrated value of the assisted wheelchair is shown in Fig. 3 (x-axis: front–back direction), Fig. 4 (y-axis: left–right direction), and Fig. 5 (z-axis: up–down direction).

A correlation was found between before and after in Fig. 3 and above and below in Fig. 5, and 80 and 240 kPa have high values. In addition, the left and right sways in Fig. 4 are higher at 80 kPa than at other pressures, and the sway is large.

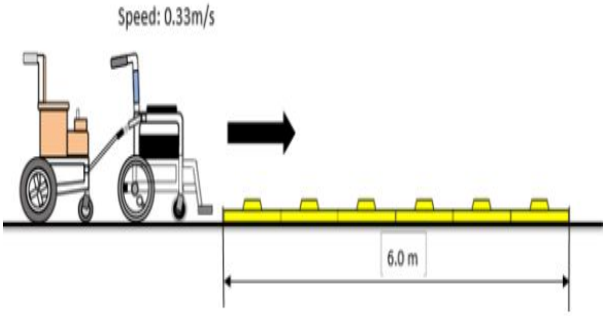


**Figure 2:** Experimental procedure.

**Table 1.** Experimental conditions.

| Acceleration sensor installation position | Dummy weight (kgf) | Tire pressure | Number of trails (times) |
|---|---|---|---|
| On a dummy heavy object installed in an assisting manual wheelchair | 50 | 80<br>160<br>240<br>320 | 10 |

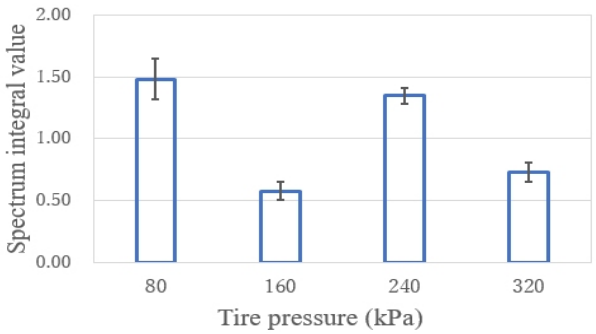


**Figure 3:** Spectrum integral value (x-axis: longitudinal direction).

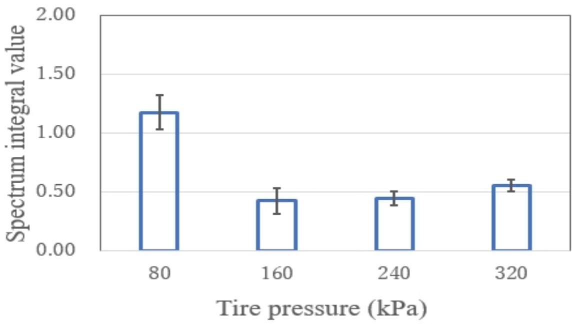


**Figure 4:** Spectrum integral value (y-axis: lateral direction).

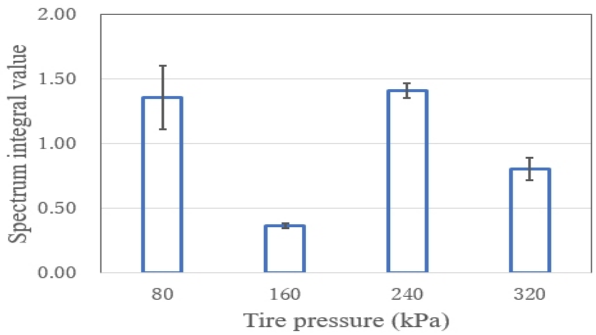


**Figure 5:** Spectrum integral value (z-axis: vertical direction).

## RIDE QUALITY AT EACH TIRE PRESSURE

### Outline of Evaluation Experiment

The experiment analyzed 23 healthy participants. The SD method was used as the evaluation method, and stationary and running evaluations were performed. The evaluation items consisted of three items (sitting comfort, sense of security, and sitting comfort of the buttocks) for both static and running conditions and the strength of shaking while running. Responses were obtained on a 5-point scale (1–5). Four tire pressures were used: 80, 160, 240, and 320 kPa.

### Evaluation of the Experiment Method

When pushing the manual assistive wheelchair, an electric wheelchair was used to maintain a constant speed. The running route was laid out with linear blocks (6.0 m). At each tire pressure, the participants got on the manual assistive wheelchair at rest and then answered the questionnaire. Thereafter, they got on the manual assistive wheelchair again, ran the wheelchair, and answered the questionnaire after running. This process was performed with the four tire pressure conditions.

### Results of the Evaluation Experiment

Fig. 6 shows the results of the sitting comfort, sense of security, sitting comfort of the buttocks and strength of shaking during running. The comfort of the buttocks tended to be lower when the tire pressure was higher. The tire pressure of 320 kPa was felt more strongly than 240 kPa. In addition, the strength of shaking was felt most strongly at 80 kPa.

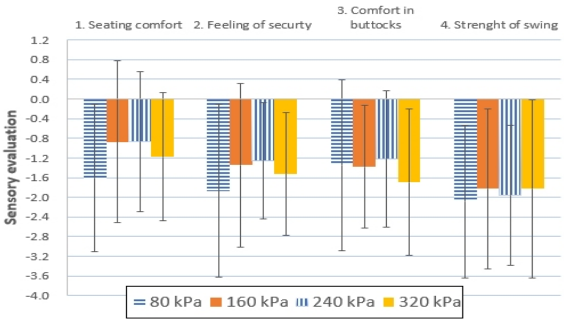


**Figure 6**: Sensory evaluation.

## CONSIDERRATION

The experiment was conducted with 17 participants. The linear blocks for the visually impaired were used, a simple concave–convex road was made, and a measurement experiment was conducted. However, actual roads may have large and small steps, and irregular and shorter vibrations are expected. Therefore, it is difficult to say that the overall load on wheelchair users could be measured. As limitations, the participants were healthy people in their 20s to 40s, and data were obtained from 17 participants only. Thus, we plan to conduct sensory evaluations using the SD method in a larger group of older people and people with disabilities and clarify the relationship between tire air pressure and vibration (Booka et al., 2015) over similar tire pressures.

## CONCLUSION

In this study, we attached an air pressure indicator for English valves to a manual wheelchair for caregivers and measured vibrations under controlled conditions. In our experiments using the manufactured vibration-measuring device, the vibration tends to increase as the tire pressure rises; the higher the tire pressure, the worse the ride comfort. However, when the tire pressure decreases, the force required to push the manual assistive wheelchair increases. Therefore, it is necessary to investigate the optimum tire pressure for caregivers according to usage conditions.

## REFERENCES

Booka, Masayuki, Ikuo Yoneda, Tsutomu Hashizume, Lee Hokyoo, Hidehisa Oku, & Shoichiro Fujisawa, "Effect of pressure to physical workload at operating a manual wheelchair," assistive technology, Studies in Health Technology and Informatics, Vol. 217, pp. 929–934 (2015).

Cook, A. M., & Polgar, J. M., "In Cook & Hussey's assistive technologies: Principles and practice," framework for assistive technologies, 3rd ed., Vol. 4, pp. 34–53 (2008).

Di Giovine, Carmen, Amy Darragh, Theresa Berner, & Taylor Duncan, "Research on wheelchair vibration offers consumer and clinician insight," RESNA 2015 (2015a).

Di Giovine, Carmen, Amy Darragh, Theresa Berner1, & Taylor Duncan, "The Effect of whole body vibration on power wheelchair mobility: a focus group," RESNA ANNUAL CONFERENCE 2015 (2015b).

Kitazaki, S., & Griffin, M. J., "Resonance behaviour of the seated human body and effects of posture," Journal of Biomechanics, Vol. 31, No. 2, pp. 143–149 (1998).

LaPlante, Mitchell P., & H. Stephen Kaye, "Demographics and trends in wheeled mobility equipment use and accessibility in the community," Assistive Technology, Vol. 22, No. 1, pp. 3–17; quiz 19 (2010).

Wilder, D. M. L., Magnusson, J. Fenwick, & M. Pope, "The effect of posture and seat suspension design on discomfort and back muscle fatigue during simulated truck driving," Applied Ergonomics, Vol. 25, No. 2, pp. 66–76 (1994).